Oxidation and Reduction

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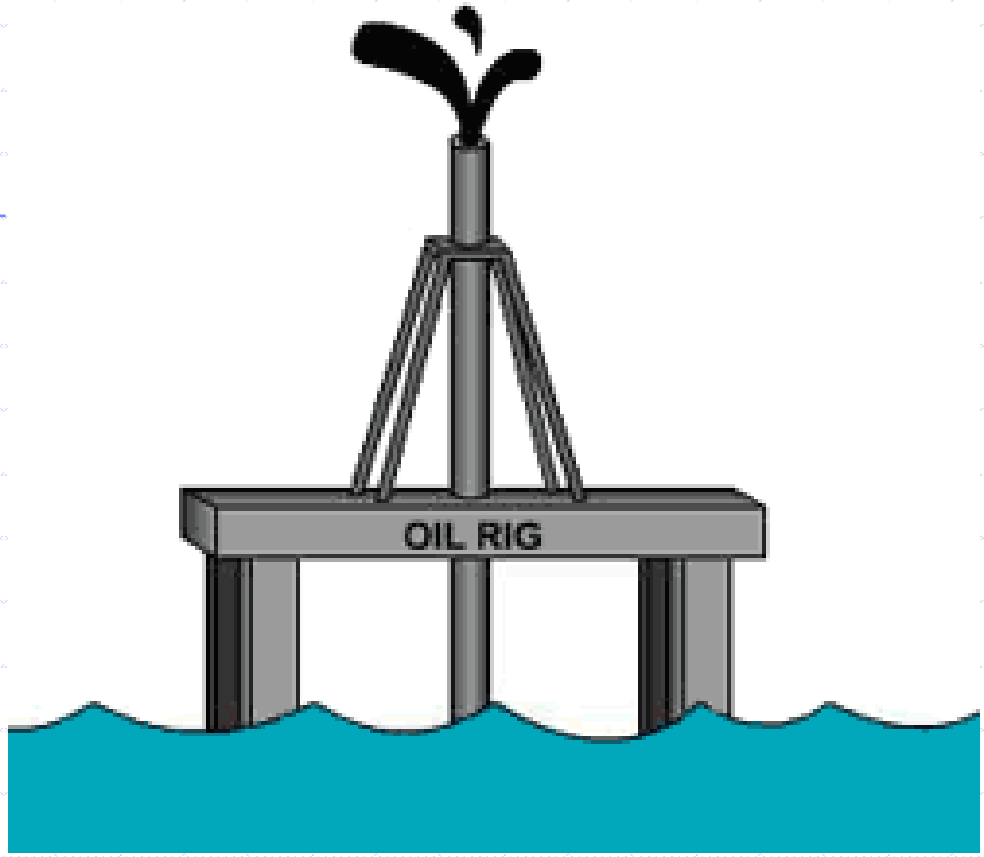
Pneumonic Devices….

- There are two phrases to help you remember the general practice of oxidation and reduction exchanges
  - LEO says GER
  - OIL RIG

LEO says.....

LEO: Loss of Electrons = Oxidation

GER: Gain of Electrons = Reduction



OIL: Oxidation is Loss....

RIG: Reduction is Gain....

....of electrons

Oxidation Numbers

- Oxidation is the loss of electrons; Reduction is the gain of electrons
- Oxidation and reduction go together. Whenever a substance loses electrons another substance gains electrons
- Oxidation Numbers are a system that we can use to keep track of electron transfers

Oxidation Numbers

	Oxidation numbers always refer to single atoms	
	The oxidation number of an uncombined element is always 0	**O_2, H_2, Ne** **Zn**
	The oxidation number of Hydrogen is usually +1 Hydrides are an exception They are -1	**HCl, H_2SO_4**
	The oxidation number of Oxygen is usually -2 Peroxides are an exception They are –1 In OF_2 oxygen is a +2	H_2O, NO^2, et
	Oxidation numbers of monatomic ions follow the charge of the ion	O^{2-}, Zn^{2+}
	The sum of oxidation numbers is zero for a neutral compound or could be the charge on a polyatomic ion	$LiMnO_4$ SO_4^{2-}

Practice Assigning Oxidation Numbers

NO_2	
N_2O_5	
$HClO_3$	
HNO_3	
$Ca(NO_3)_2$	
$KMnO_4$	

Practice Assigning Oxidation Numbers

$Fe(OH)_3$	
$K_2Cr_2O_7$	
CO_3^{2-}	
CN^-	
$K_3Fe(CN)_6$	

Practice Assigning Oxidation Numbers

NO_2	N= +4, O = -2
N_2O_5	N = +5, O = -2
$HClO_3$	H=+1, Cl=+5, O = -2
HNO_3	H=+1, N = +5, O = -2
$Ca(NO_3)_2$	Ca=+2, N =+5, O= -2
$KMnO_4$	K=+1, Mn=+7, O= -2

Hint: If it includes a polyatomic ion, you know the overall charge, and oxygen will always be -2, find the other oxidation states next

Practice Assigning Oxidation Numbers

$Fe(OH)_3$	Fe =+3, O=-2, H=+1
$K_2Cr_2O_7$	K=+1, Cr=+6, O=-2
CO_3^{2-}	C=+4, O =-2
CN^-	C=+4, N=-5
$K_3Fe(CN)_6$	K=+1, Fe=+3, C=+4, N=-5

Hint: If it includes a polyatomic ion, you know the overall charge, and carbon will most often be +4, find the other oxidation states next

Using Oxidation Numbers

- Careful examination of the oxidation numbers of atoms in an equation allows us to determine what is oxidized and what is reduced in an oxidation-reduction reaction

Using Oxidation Numbers

- An **increase** in the oxidation number indicates that an atom has **lost electrons** and therefore **oxidized.**
- A **decrease** in the oxidation number indicates that an atom has **gained electrons** and therefore **reduced**
- Example

$$\overset{0}{Zn} + \overset{+2\ +6\ -2}{CuSO_4} \rightarrow \overset{+2\ +6\ -2}{ZnSO_4} + \overset{0}{Cu}$$

Zn: **0** → **+ 2** → **Oxidized**

Cu: **+2** → **0** → **Reduced**

Exercise

For each of the following reactions find the element **oxidized** and the element **reduced**

$Cl_2 + KBr \rightarrow KCl + Br_2$

$Cu + HNO_3 \rightarrow Cu(NO_3)_2 + NO_2 + H_2O$

$HNO_3 + I_2 \rightarrow HIO_3 + NO_2$

- Look on the following slides for answers.....

Exercise 1

For each of the following reactions find the element **oxidized** and the element **reduced**

$$\overset{0}{Cl_2} + \overset{+1\ -1}{KBr} \rightarrow \overset{+1\ -1}{KCl} + \overset{0}{Br_2}$$

Br increases from **–1 to 0** → **Oxidized**

Cl decreases from **0 to –1** → **Reduced**

K remains unchanged at +1

Exercise 2

For each of the following reactions find the element **oxidized** and the element **reduced**

$$\overset{0}{Cu} + \overset{+1\ +5\ -2}{HNO_3} \rightarrow \overset{+2\ +5\ -2}{Cu(NO_3)_2} + \overset{+4\ -2}{NO_2} + \overset{+1\ -2}{H_2O}$$

Cu increases from 0 to +2 → **Oxidized**

Some N in nitric acid from +5 to +4 → **Reduced**

The nitrogen that ends up in copper nitrate remains unchanged, same for hydrogen and oxygen

Exercise 3

For each of the following reactions find the element **oxidized** and the element **reduced**

$$\overset{1\ \mathbf{+5}\ -2}{HNO_3} + \overset{\mathbf{0}}{I_2} \rightarrow \overset{+1\ \mathbf{+5}\ -2}{HIO_3} + \overset{\mathbf{+4}\ -2}{NO_2}$$

N is reduced from +5 to +4 → **Reduced**

I is increased from 0 to +5 → **Oxidized**

The hydrogen and oxygen remain unchanged.

Oxidation-Reduction Reactions

- All redox reactions have at least one element **oxidized** and at least one element **reduced**
- Occasionally the same element may undergo both oxidation and reduction.
  - This is known as an **auto-oxidation reduction**

Balancing Redox Reactions

- Many chemical reactions involving oxidations and reductions are complex and very difficult to balance by the "guess and check" methods we learned earlier.
- For complicated reactions a more systematic approach is required

Balancing Redox Reactions

There are several basic steps

1. Assign oxidation numbers to the species in the reaction
2. Find the substance oxidized and the substance reduced
3. Write half reactions for the oxidation and reduction
4. Balance the atoms that change in the half reactions
5. Determine the electrons transferred and balance the electrons between the half reactions
6. Combine the half reactions and balance the remaining atoms
7. Check your work. Make sure that both the atoms and charges balance

Lets try some examples……

Balancing Redox Equations 1

1. Assign oxidation numbers to the species in the reaction
2. Find the substance oxidized and the substance reduced
3. Write half reactions for the oxidation and reduction
4. Balance the atoms that change in the half reaction
5. Determine the electrons transferred and balance the electrons between the half reactions
6. Combine the half reactions and balance the remaining atoms
7. Check your work. Make sure that both the atoms and charges balance

0 +1 **+5** -2 **+2** +5 -2 **+2** -2 +1 -2

$Cu + HNO_3 \rightarrow Cu(NO_3)_2 + NO + H_2O$

Copper Oxidized, some Nitrogen Reduced

$Cu \rightarrow Cu^{2+} + 2e^-$ $N^{5+} + 3e^- \rightarrow N^{2+}$

*both are balanced

2 e- ox, 3 e- red, lowest common multiple = 6 e-

$3Cu \rightarrow 3Cu^{2+} + 6e^-$ $2N^{5+} + 6e^- \rightarrow 2N^{2+}$

$3Cu + 2N^{5+} + 6e^- \rightarrow 3Cu^{2+} + 6e^- + 2N^{2+}$

*Ratio of Cu compounds to NO (5+) must be 3:2

$3Cu + \_\_HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + \_\_H_2O$

*Next balance out the nitrogen (total)

$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + \_\_H_2O$

*Balance the final product

$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

Balancing Redox Equations 2

1. Assign oxidation numbers to the species in the reaction
2. Find the substance oxidized and the substance reduced
3. Write half reactions for the oxidation and reduction
4. Balance the atoms that change in the half reaction
5. Determine the electrons transferred and balance the electrons between the half reactions
6. Combine the half reactions and balance the remaining atoms
7. Check your work. Make sure that both the atoms and charges balance

+1 +5 -2 0 +1 +5 -2 +4 -2 +1 -2

$HNO_3 + I_2 \rightarrow HIO_3 + NO_2 + H_2O$

Iodine Oxidized, some Nitrogen Reduced

$I^0 \rightarrow I^{5+} + 5e^-$ $N^{5+} + 1e^- \rightarrow N^{4+}$

$I_2^0 \rightarrow 2I^{5+} + 10e^-$ $N^{5+} + 1e^- \rightarrow N^{4+}$

*both are balanced

10 e- ox, 1 e- red, lowest common multiple = $10e^-$

$I_2^0 \rightarrow 2I^{5+} + 10e^-$ $10\ N^{5+} + 10e^- \rightarrow 10N^{4+}$

$I_2^0 + 10\ N^{5+} + 10e^- \rightarrow 2I^{5+} + 10e^- + 10N^{4+}$

*Ratio of N compounds to I must be 5:1

$5\ HNO_3 + 1\ I_2 \rightarrow 1\ HIO_3 + 5\ NO_2 + \_\_\ H_2O$

*Next balance out the water

$5\ HNO_3 + 1\ I_2 \rightarrow 1\ HIO_3 + 5\ NO_2 + 2\ H_2O$

Balancing Ionic Redox Equations 3

1. Assign oxidation numbers to the species in the reaction
2. Find the substance oxidized and the substance reduced
3. Write half reactions for the oxidation and reduction
4. Balance the atoms that change in the half reaction
5. Determine the electrons transferred and balance the electrons between the half reactions
6. Combine the half reactions and balance the remaining atoms. You may need to add H+ or OH- and H_2O in ionic equations
7. Check your work. Make sure that both the atoms and charges balance

$Fe^{2+} + MnO_4^- \rightarrow Mn^{2+} + Fe^{3+}$ (acidic)

Balancing Ionic Redox Equations 4

1. Assign oxidation numbers to the species in the reaction
2. Find the substance oxidized and the substance reduced
3. Write half reactions for the oxidation and reduction
4. Balance the atoms that change in the half reaction
5. Determine the electrons transferred and balance the electrons between the half reactions
6. Combine the half reactions and balance the remaining atoms. You may need to add H+ or OH- and H_2O in ionic equations
7. Check your work. Make sure that both the atoms and charges balance

$Br_2 \rightarrow BrO_3^- + Br^-$ **(basic)**

Balancing Ionic Redox Equations 5

1. Assign oxidation numbers to the species in the reaction
2. Find the substance oxidized and the substance reduced
3. Write half reactions for the oxidation and reduction
4. Balance the atoms that change in the half reaction
5. Determine the electrons transferred and balance the electrons between the half reactions
6. Combine the half reactions and balance the remaining atoms. You may need to add H^+ or OH^- and H_2O in ionic equations
7. Check your work. Make sure that both the atoms and charges balance

$VO_2^+ + Zn \rightarrow VO^{2+} + Zn^{2+}$ (Acidic)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